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A New Architecture for Improving Location Management in PCS Networks

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Abstract: This study proposes a new architecture for improving the location management in PCS networks. The proposed architecture employs several HLRs as opposed to one HLR in the IS-41 and GSM models. Indeed, the new architecture associates with each MU two types of HLRs ; a resident HLR that serves the location areas in which the MU often resides and a serving HLR that serves the MU when it is roaming outside its resident HLR covering area. All the possible location update and location search scenarios of the proposed architecture are discussed. This analysis shows that the performance of the proposed scheme varies according to the user moving patterns. Numerical results are promising and a significant cost reduction can be obtained with the new architecture.

Key words: Location Management, Mobility Management, IS-4, GSM-MAP

INTRODUCTION

Personal Communication Service (PCS) networks divide the coverage area into many Location Areas (LA) [1]. Each LA is a set of cells. Mobile Units (MUs) within a cell communicate with the cell base station through radio channels. The base stations within a LA are connected trough wirelines to a Mobile Switching Center (MSC). Signaling System No. 7 (SS7) is used to carry user information and signaling messages between the MSC's and the network databases [2,3].

In PCS, location management enables the network to determine the MU's current LA for call delivery. It is a two-phase process implying location update and location search. Location update occurs when the MU enters a new LA and notifies the network of its new location. Location search occurs when an MU is called; in which case the network database is queried in order to determine the MU's current LA. Currently, there are two commonly used standards for location management: Interim Standard 41 (IS-41) [2,3] and the Global System for Mobile (GSM) Mobile Application Part (MAP) [4]. Both standards employ a two-level database architecture consisting of one Home Location Register (HLR) and many Visitor Location Registers (VLRs), referred to as HLR/VLR(s) architecture in this study and shown in Fig. 1. In this architecture, the HLR serves the entire network and is considered the centralized database of the network. It permanently stores the location profile and subscriber parameters of its assigned MUs. The VLR serves one LA or more and stores all the relevant parameters of the MUs that roam within the LA(s) that it controls. It is usually collocated with an MSC.

In the HLR/VLRs architecture, the network database HLR is consulted during the processing of an incoming call. Conversely, the HLR is updated as the MU moves to a new LA and is serviced by different VLR within the network. Querying the HLR every time a location search or a location update is performed results in tremendous strain on the use of the network resources due to the signaling traffic and database access load. This may significantly degrade the performance of the network with today's high number of subscribers [5]. Reduction of signaling and database access traffic constitutes a growing research issue. Several strategies have been recently proposed. Some of these strategies are based on the HLR/VLRs architecture [6-14]. Some others present an alternative architecture [15-17].

A location forwarding strategy is proposed to reduce the signaling cost for location update [7,9]. With this strategy, whenever an MU moves to a new LA, a pointer is established from the old LA to track the MU. This may lead, after k moves, to a chain of k pointers. Consequently, a cost penalty is paid during the location search since a chain of k pointers must be traversed. A built-in memory model is proposed to reduce cost of the location update procedure [13]. It requires the addition of a small built-in memory to the MU that stores the same location information (MU's location area address) as in the HLR. When the MU changes its LA, it queries the LA

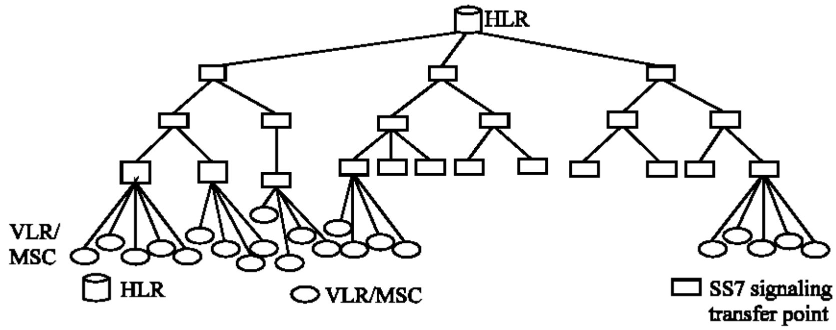

Fig. 1: HLR/VLRs architecture

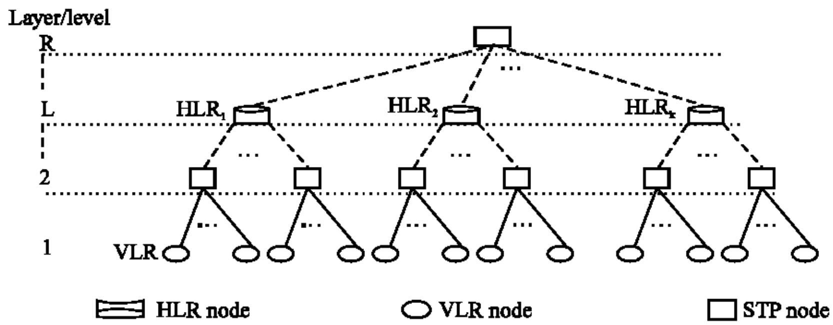

Fig. 2: Proposed Architecture

whose address is stored in the MU built-in memory to create a pointer between that LA and the MU's new LA. Hence, no location update operation is performed in the HLR. When the MU is called, its HLR is queried to search its LA. If the MU no longer resides in that LA, then its current LA is reached by traversing a single pointer. A profile-based strategy that is combined with the built-in memory method is presented to reduce the signaling cost of location update by increasing the intelligence of the location procedure [11]. MU's location information is replicated/cached at selected local databases to reduce the cost of the location search [10]. When MU changes its location, all replicated databases need to be updated incurring a high database access load and significant signaling traffic. Strategies that combine forwarding scheme and caching/replication mechanism are introduced by Chen and Gu [8], Safa *et al.*[12]. Distributed database driven architectures are proposed by Anantharm *et al.*[15] and Wang [17]. In these architectures, the HLR/VLRs architecture is replaced by a large number of location databases that are organized as a tree with the root at the top and the leaves at the bottom. The MUs are associated with the leaf databases. Each database contains the location data of the MUs that are residing in its subtree. When an MU moves to a new LA belonging to a different leaf database, all the databases along the path from its old LA to its new LA are updated to indicate the correct location of the MU. When a call is initiated the databases are queried sequentially, starting from the database of the calling MU and going up till reaching a database that contains an entry for the called MU, then following this entry down till the MU is located. This architecture reduces the distance traveled by signaling messages but increases significantly the database access, which results in large processing delays for location update and location search procedures. A similar architecture is proposed by Mao and Douligeris[16] but it uses a three-level tree to represent the covered region.

There is a common drawback with the architectures proposed in most of these previous studies. The crash of the root database (or master database) may paralyze the entire system. In this context, the study proposes a new architecture to improve the performance of the location management in the PCS networks.

THE PROPOSED ARCHITECTURE

The proposed architecture employs several HLRs instead of one HLR as shown in Fig. 2. Each HLR may serve several VLRs. A VLR can serve one or more LAs but it can be served only by one HLR. For each MU two types of HLRs are defined: a resident HLR and a serving HLR. The MU's resident HLR covers the LAs in which the MU often resides. It stores permanently the MU location information and parameters. The MU's serving HLR serves the MU when it is roaming outside its resident HLR covering area. When the MU moves to a new LA not served by its resident HLR, the HLR that serves this LA becomes the MU's serving HLR as explained in location update procedure.

When an MU is called, the VLR of the calling unit verifies if the called MU is local. If it is, then the called MU is located. Otherwise, the VLR forwards the call request to its HLR which verifies whether the called MU's is roaming in its covering area but under different VLR or in the covering area of another HLR. Then this HLR forwards the call request to the appropriate network entity, as explained in location search procedure.

Location update procedure: The proposed architecture distinguishes between several types of MU moves: intra-VLR move, intra-HLR move and inter-HLR move. In what follows, we present the location update scenarios associated with these moves.

Intra-VLR move: This move occurs when the MU moves between two LAs that belong to the same VLR. The MU's location profile is then updated only at the VLR level.

Intra-HLR move: This move occurs when the MU moves between two LAs served by two different VLRs but within the covering area of the same HLR. Its main steps, shown in Fig. 3 are described as following:

- The MU moves to a new LA served by a different VLR and registers with this VLR.
- The VLR of the new LA sends a location update request to its HLR.
- The HLR, in its turn, sends a location cancellation request to the VLR of the old LA.
- The old VLR sends a location cancellation acknowledgment to the HLR.
- Upon receiving this acknowledgment, the HLR acknowledges the location update to the new VLR, which instructs the new LA to start serving the MU.

Inter-HLR move: This move occurs when the MU between two LAs are served by two VLRs that belong to two different HLRs. In this context, three cases are studied:

a) The MU leaves the covering area of its resident HLR and enters the covering area of another HLR. This new HLR becomes the MU's serving HLR.
b) The MU returns to its resident HLR, i.e. the MU returns to the covering area of its resident HLR from the covering area of another HLR.
c) The MU moves between two distinct HLRs that are different than its resident HLR.

The main steps of this scenario are described as following:

1. The MU enters a new LA and registers with the VLR of this LA.
2. If the case a) prevails, then:
- The VLR of the new LA sends a location update request to its HLR. This HLR becomes the serving HLR for the MU (serving HLR 1 in Fig. 4).
- The serving HLR sends a location update request to the MU's resident HLR.
- The resident HLR sends a registration cancellation request to the old VLR.
- The old VLR sends a cancellation acknowledgment to the resident HLR.
- Upon receiving this acknowledgment, the resident HLR updates the profile of the MU and sends a location update acknowledgment to the serving HLR.
- The serving HLR, in its turn, sends a registration acknowledgment to the current VLR of the MU. Then this VLR starts to serve the MU.
3. If the case b) prevails, then:
- The MU's new VLR sends a location update request to its HLR, which is the MU's resident HLR.
- The resident HLR forwards this request to the MU's old serving HLR.
- The old serving HLR sends a cancellation request to the MU's old VLR.
- The old VLR acknowledges the cancellation request.
- The old serving HLR forwards the acknowledgment to the MU's resident HLR then it deletes the MU profile. The resident HLR updates the MU profile.
- The resident HLR, in its turn, sends a location update acknowledgment to the VLR of the new LA, which starts, in its turn, serving the MU.

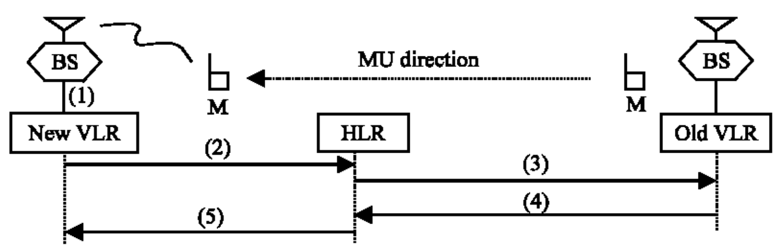

Fig. 3: Location update procedure of an intra-HLR move

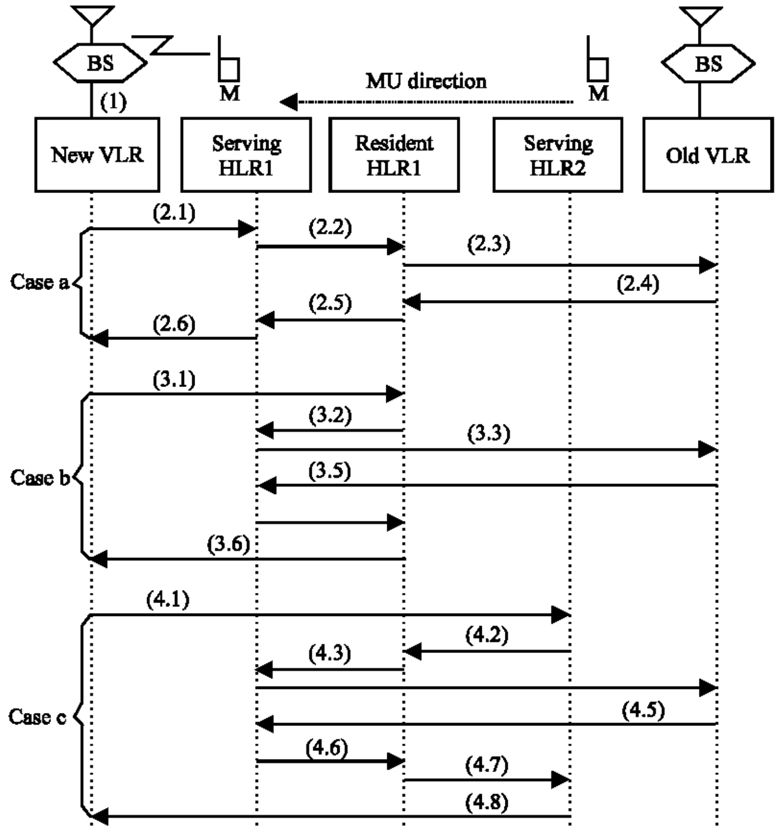

Fig. 4: Location update procedure for an inter-HLR move

4. If the case c) prevails, then:

- The VLR of the new LA sends a location update request to its HLR. This HLR becomes the MU's new serving HLR (Serving HLR2 in Fig. 4).
- The new serving HLR sends a location update request to resident HLR. The resident HLR updates the MU profile to indicate its new serving HLR.
- The MU's resident HLR, in its turn, sends a registration cancellation request to the MU's old serving HLR (Serving HLR1 in Fig. 4).
- The old serving HLR forwards the cancellation request to the MU's old VLR.
- The old VLR sends a cancellation acknowledgment to the old serving HLR.
- Upon receiving this acknowledgement, the old serving HLR forwards the acknowledgement to the MU's resident HLR and deletes the MU profiles.
- The resident HLR acknowledges the location update to the new serving HLR which updates the MU profile to indicate the VLR of its new LA.
- The new serving HLR sends a location update acknowledgment to the new VLR. Upon receiving this acknowledgment, the new VLR starts serving the MU.

Location search procedure: An algorithm that illustrates the location search procedure in the proposed model is presented in Fig. 5. The main purpose of this procedure is to determine the MU's current LA in order to deliver a call. For sake of simplicity, we assume that the MU, N is calling the MU, M. The algorithm considers the following three possible scenarios:

1. M and N are served by the same VLR: The call is local and is handled by the VLR.
2. M and N are served by two different VLRs but both VLRs are served by the same HLR.
3. M and N are served by two different VLRs that belong to two different HLRs: In this context, the following cases are possible:

- M is roaming in the covering area of its resident HLR.
- N is roaming in the covering area of M's resident HLR but M is not in its resident HLR.
- M and N are roaming outside of M's resident HLR.

```
If (N and M are served by the same VLR) then
        Local Call
Else {
        N's VLR sends a call request to its HLR.
        If (N's VLR and M's VLR are served by the same HLR) then {
        HLR transfers the call request to M's VLR.
        M's VLR instructs the MSC to assign a TLDN for the call and returns it to the HLR in an acknowledgment message.
        The HLR forwards this TLDN to N's VLR.
        }
        Else if (M is roaming in the covering area of its resident HLR) then {
        N's serving HLR forwards the query to M's resident HLR.
        M's resident HLR forwards the request to M's current VLR.
        M's VLR returns a TLDN for the call to M's resident HLR.
        M's resident HLR forwards it to N's serving HLR.
        N's serving HLR transfers it to the N's current VLR.
        }
        Else if (N's serving HLR is M's resident HLR) then {
         M's resident HLR, which is N's HLR, determines M's serving HLR and forwards the call to it.
         M's serving HLR transfers the call to the M's current VLR.
         M's VLR assigns a TLDN for the call and returns it in an ack message to M's serving HLR.
         M's serving HLR forwards it to the calling HLR (i.e., N's serving HLR)
         N's serving HLR forwards this TLDN to N's current VLR.
        }
        Else {
        N's serving HLR transfers the query to M's resident HLR.
        M's resident HLR determines M's serving HLR then forwards the call to it.
        M's serving HLR transfers the request to M's current VLR.
        M's VLR assigns a TLDN to the call and returns it in an ack message to the M's serving HLR.
        M's serving HLR forwards it to M's resident HLR.
        M's resident HLR forwards this TLDN to N's serving HLR.
        N's HLR transfers the response to N's current VLR.
        }
Then the communication is established between the N's LA and M's LA.
```

Fig. 5: Location search algorithm (M: calle MU, N: calling MU)

PERFORMANCE ANALYSIS

We present an analytical model to evaluate the performance of the proposed architecture and compare it with the HLR/VLRs and the database driven architectures. In this analysis, we use a hierarchical tree of R layers, as shown in Fig. 2. The layer R contains the root node and the layer 1 contains the leaf nodes. In the database driven scheme proposed[15-17], a database is installed on each node of the tree and the MUs are assigned to the leaf nodes. In the HLR/VLRs scheme, the network database, HLR, is situated on the only node of layer R and the VLRs are installed on the leaf nodes. In the proposed scheme, the HLRs are installed on the nodes of layer L (1<L<R), while the VLRs remains installed on the leaf nodes. Then, we denote by:

- $m_{x,y}$ Layer of the closest common node to LA x and LA y.
- p Probability that the MU move is intra-VLR.
- q Probability that the called and the calling MUs are served by the same VLR.
- α Probability that the MU move is inter-HLR.
- β Probability that the MU's resident HLR is involved in the inter-HLR move, i.e., the MU leaves or returns to its resident HLR covering area.
- δ Probability that the calling MU and the called MU are roaming in the covering areas of two different HLRs.
- n New LA of the MU.
- a Old LA of the MU.
- s LA of the calling unit (source).
- d LA of the called MU (destination).
- θ Probability that the call is originated from or terminated at the called MU's resident HLR covering area.

We define $P(m_{x,y}=i)$ to be the probability that the closest common node to LA x and LA y is in layer i. This probability can be given by the following equation[14]:

$$P(m_{a,n}=i)=\begin{cases} p(1-p)^{i-1} & \text{for } i=1,2,\ldots,R-1 \\ (1-p)^{i-1} & \text{for } i=R \end{cases} \quad (1)$$

$$P(m_{s,d}=i)=\begin{cases} q(1-q)^{i-1} & \text{for } i=1,2,\ldots,R\text{-}1 \\ (1-q)^{i-1} & \text{for } i=R \end{cases} \quad (2)$$

We furthermore denote the costs of various operations used in this analysis as follows:

$T(i,j)$	Cost of transmitting a message over a link between two adjacent layers i and j.
$C_m(i)$	Cost of accessing or updating a database in layer i.
$M_{Proposed}$	Estimated cost of a location update in the proposed scheme.
$M_{HLR/VLRs}$	Estimated cost of a location update in the HLR/VLRs architecture
$M_{database\ driven}$	Estimated cost of a location update in the database driven architecture.
$R_{Proposed}$	Estimated cost of a location search in the proposed scheme.
$R_{HLR/VLRs}$	Estimated cost of a location search in the HLR/VLRs architecture.
$R_{database\ driven}$	Estimated cost of a location search in the database driven architecture.

The estimated cost of a location update in the proposed scheme is given by:

$$\begin{aligned} M_{Proposed} &= P(m_{a,n}=1) * C_m(1) + \\ &\sum_{i=2}^{L} P(m_{a,n}=i) \times (2C_m(1) + C_m(L) + 4T(1,L)) \\ &+\alpha \times \Bigg\{ 2C_m(1) + C_m(L) + 4T(1,L) + \sum_{i=L+1}^{R} P(m_{a,n}=i) \\ &\times \Bigg[\beta \times \left(\sum_{j=L}^{i-1} 4T(j,j+1) + C_m(L) \right) \\ &+(1-\beta) \times \left(\sum_{j=L}^{i-1} 8T(j,j+1) + 2C_m(L) \right) \Bigg] \Bigg\} \end{aligned} \tag{3}$$

where:

$$\alpha = 1 - \sum_{i=1}^{L} P(m_{a,n}=i)$$

Equation 3 can be explained as follows. The first part illustrates the cost of the location update procedure of an intra-VLR move and intra-HLR move. The second part illustrates the scenario after an inter-HLR move. $T(1,L) = T(1, 2) + T(2, 3) +\ldots+ T(L-1, L)$ is equal to the cost of traversing links between a node of layer 1 (i.e., VLR) and the node of layer L (i.e., where an HLR is located in the proposed scheme). This cost is multiplied by 4 because, when a signaling message is sent from an VLR to the HLR, the latter sends a similar message to the old VLR. By adding the cost of the acknowledgment from the old VLR to the HLR and then from the HLR to the current VLR, we can justify the 4 T(1,L). Similar analysis applies on transmitting costs in second part of the equation.

For comparison purposes, we need the costs of the HLR/VLRs architecture and the database driven architecture. The estimated cost of the location update of the HLR/VLRs architecture is given by:

$$M_{HLR/VLRs} = P(m_{a,n}=1) \times C_m(1) + \sum_{i=2}^{R} \left\{ \begin{matrix} P(m_{a,n}=i) \times 2C_m(1) \\ +C_m(R) + 4T(1,R) \end{matrix} \right\} \tag{4}$$

In the database driven architecture, the location update occurs at all the databases on the path between the old LA and the new LA. Therefore, the estimated cost of a location update operation in this scheme can be written as following:

$$M_{Database\ driven} = \sum_{i=1}^{R} P(m_{a,n}=i) \times \left\{ \sum_{j=1}^{i-1} \begin{bmatrix} 4T(j,j+1)+ \\ 2C_m(j) \end{bmatrix} + C_m(i) \right\} \tag{5}$$

The estimated cost of the location search procedure in the proposed scheme is given by:

$$\begin{aligned} R_{Proposed} &= P(m_{s,d}=1) \times C_m(1) + \sum_{i=2}^{L} P(m_{s,d}=i) \times \\ &(C_m(1) + C_m(L) + 4T(1,L)) + \\ &\delta \times \left\{ \begin{aligned} &C_m(1) + C_m(L) + 4T(1,L) + \\ &\theta \times \left[\begin{aligned} &\sum_{i=L+1}^{R} P(m_{s,d}=i) \times \\ &\left(\sum_{j=L}^{i-1} 4T(j,j+1) + C_m(L) \right) \end{aligned} \right] \\ &+ (1-\theta) \times \left[\sum_{i=L+1}^{R} P(m_{s,d}=i) \right] \\ &\times \left(\sum_{j=L}^{i-1} 8T(j,j+1) + 2C_m(L) \right) \end{aligned} \right\} \end{aligned}$$

where:

$$\delta = 1 - \sum_{i=1}^{L} P(m_{s,d}=i) \tag{6}$$

The first part of Eq. 6 describes the cost of the location search procedure when the call is originated from and terminated at the covering area of the same HLR. The second part illustrates the cost of this procedure when the call is originated from and terminated at the covering areas of two different HLRs.

The estimated cost of a location search in the database driven scheme is given by:

$$R_{\text{Database driven}} = \sum_{i=1}^{R} P(m_{s,d} = i) \times \left\{ \sum_{j=1}^{i-1} [4T(j, j+1) + 2C_m(j)\} + C_m(i)] \right\} \quad (7)$$

The estimated cost of the location search procedure of the HLR/VLRs scheme is given by:

$$R_{\text{HLR/VLRs}} = \sum_{i=1}^{R} P(m_{s,d} = i) \{C_m(1) + C_m(N) + 4T(1, N)\} \quad (8)$$

RESULTS

We present the numerical results of the comparison between the proposed model and HLR/VLRs and database driven models. We consider various values of R and L in order to study the impact of the location of the new HLRs on the performance of the proposed model. In this analysis, we assume that the database access cost in layer i is equal to i, the cost of crossing a link between layer i-1 and layer i is equal to i and β and θ have an equal probability value.

We denote $M_{\text{Proposed}}/M_{\text{HLR/VLR}}$, $M_{\text{database driven}}/M_{\text{HLR/VLR}}$ the relative cost of the location update procedure for the proposed model and the database driven model to that of the HLR/VLRs model, respectively. These costs are obtained from Eq. 3-5 and shown in Fig. 6. A relative cost of 1 means that the costs under both models are the same. Figure 6a shows the performance of the analyzed schemes with R = 5 and various values of L (i.e., L = 2, 3, 4). Users in Fig. 6 are classified with respect to their moves. When p is very small (i.e., The MU moves are not local), the HLR/VLR scheme outperforms the proposed scheme and the database driven scheme because a great number of signaling messages is exchanged between the HLRs and the VLRs in the proposed scheme as well as between the various databases in the database driven scheme. The latter scheme is the most costly. When p increases, a significant cost reduction is obtained with the proposed scheme when L=2 and 3. Less saving is obtained when L = 4 because the location of new HLRs becomes closer to the root (where the HLR is located in the HLR/VLRs architecture). When p = 0, the performance of the three schemes is equal. This is normal since when p = 0 the MU's moves are always local. We observe that the performance of the database driven scheme improves when p increases significantly (p>0.7) due to the decrease in the number of signaling messages during the location update when the MU's moves become local. Figure 6b shows the performance of the three

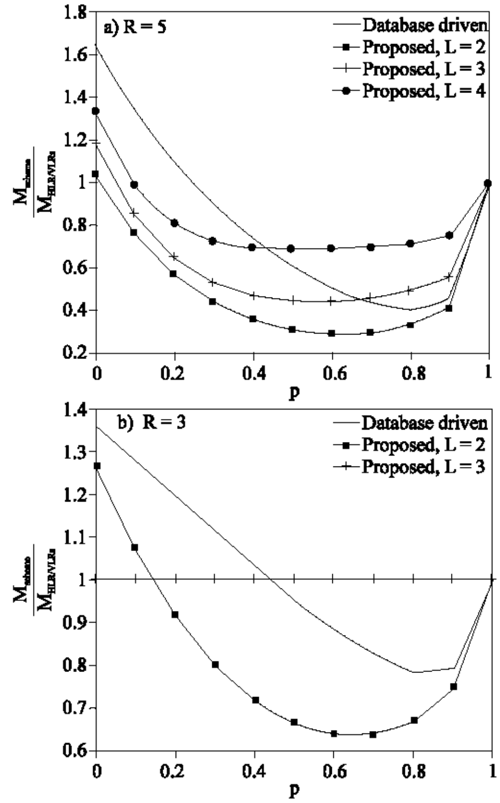

Fig. 6: Relative Cost for Location Update

schemes when R = 3. When R = 3, the database driven resembles the three-level tree architecture used in a subsystem area[16]. The Fig. 6b shows that, when L = 3, the proposed scheme resembles the HLR/VLR scheme and when L = 2 the proposed scheme always outperforms the database driven scheme.

A similar analysis can be conducted on the location search procedure. Let $R_{\text{Proposed}}/R_{\text{HLR/VLR}}$ and $R_{\text{database driven}}/R_{\text{HLR/VLR}}$ be the relative cost of the location search procedure for the proposed model and the database driven model to that of the HLR/VLRs model, respectively. These costs are obtained from Eqs. 6-8 and shown in Fig. 7. Users are classified by their location when processing an incoming call. Figure 6a shows the performance of the location search procedure in the three schemes when R = 5. We observe that, in almost all the cases, the proposed scheme results in a significant cost reduction when L = 2 and L = 3 and always outperforms the database driven scheme. The cost reduction is at its peak when q approaches 1 since in this case the probability that the called LA and the calling LA are served by the same HLR increases. Figure 7a and b show that a maximum cost reduction is obtained with the proposed scheme when L =2. The reduction decreases when the value of L increases since the new HLRs become closer to the HLR of the HLR/VLRs architecture.

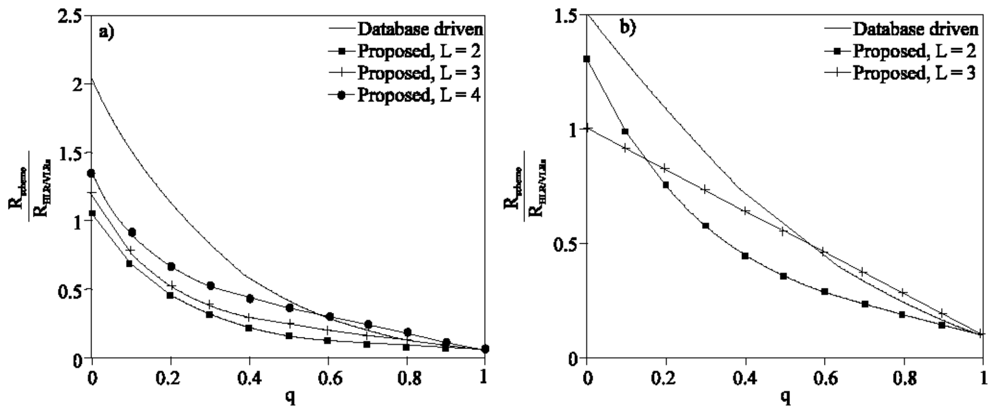

Fig. 7: Relative Cost for Location Search Procedure (a) R= 5, (b) = 3

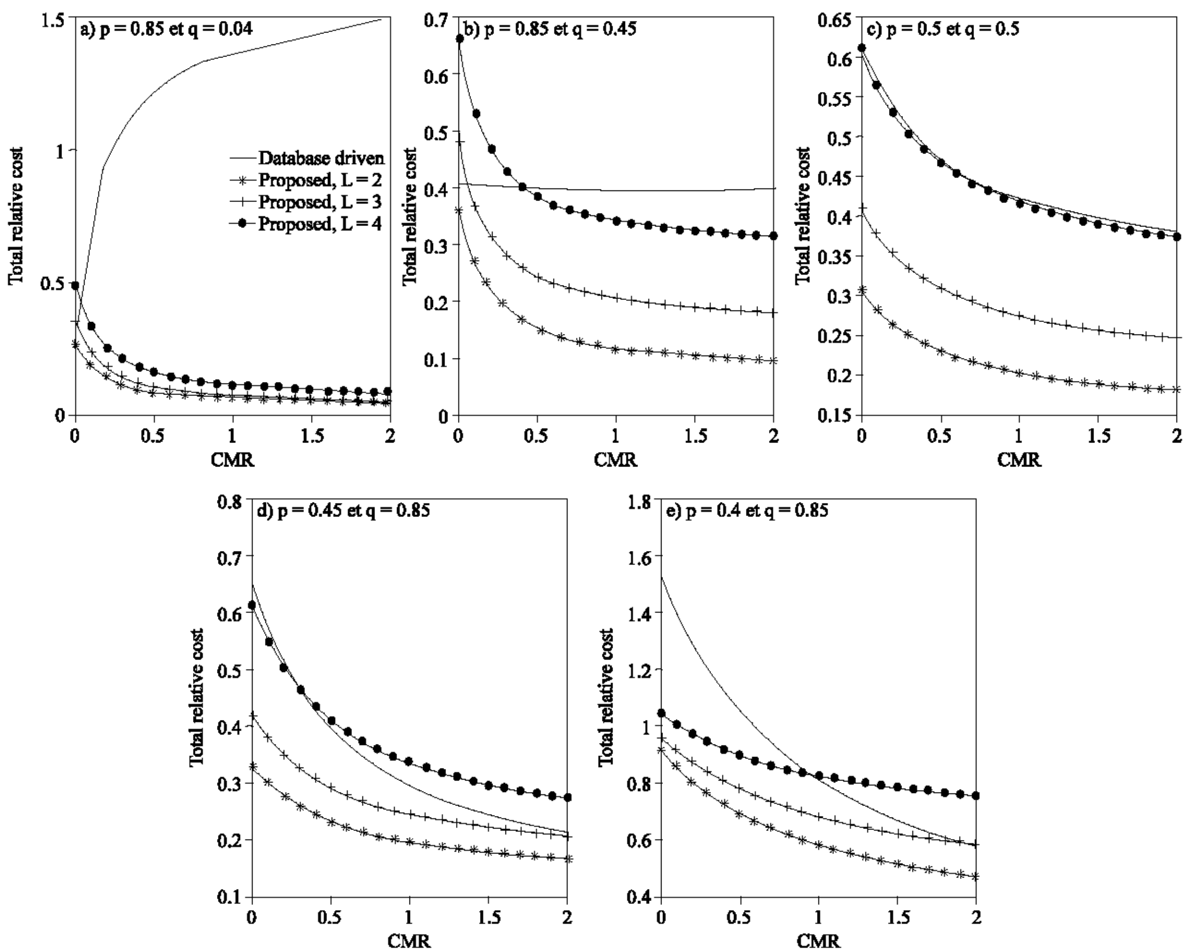

Fig. 8: Total Relative Cost of Location Ianagement Schemes

As we can conclude from the previous analysis, the performance of the location management schemes is highly dependent on users' mobility and incoming calls characteristics. In what follows, we investigate the classes of users for which the proposed scheme yields a net reduction in signaling trafic and databases loads. We classify users by their Call-to-Mobility Ratio (CMR), which is defined as the ratio between the average number of calls to an MU per unit time and the average number of times this MU changes LAs per unit time (i.e., incoming calls rate/mobility rate). Then it follows that:

$$CMR = \frac{\lambda}{\mu}$$

where, λ is the incoming calls rate and μ is the mobility rate.

We furthermore denote the estimated total cost per unit time for location update and location search in the HLR/VLRs, database driven and proposed schemes to be $C_{HLR/VLRs}$, $C_{database\ driven}$ and $C_{Proposed}$, respectively. It follows that:

$$C_{proposed} = \mu M_{Proposed} + \lambda R_{Proposed} \quad (9)$$

$$C_{HLR/VLRs} = \mu M_{HLR/VLRs} + \lambda R_{HLR/VLRs} \quad (10)$$

$$C_{database\ driven} = \mu M_{Database\ driven} + \lambda R_{Database\ driven} \quad (11)$$

Finally, we define the total relative cost of the proposed location management scheme as the ratio of the total cost per unit time for the proposed scheme to that of HLR/VLRs architecture. Similarly, the relative cost of the database driven scheme is the ratio of the total cost per unit time for this scheme to that of HLR/VLRs architecture. These costs can be derived from Eqs. 9-11 as follows:

$$\frac{C_{Proposed}}{C_{HLR/VLR}} = \frac{M_{Proposed} + CMR * R_{proposed}}{M_{HLR/VLR} + CMR * R_{HLR/VLR}} \quad (12)$$

$$\frac{C_{Database\ driven}}{C_{HLR/VLR}} = \frac{M_{Database\ driveb} + CMR * R_{Database\ driven}}{M_{HLR/VLR} + CMR * R_{HLR/VLR}} \quad (13)$$

Fig. 8 shows the total relative cost of the proposed scheme and the database driven schemes plotted against the CMR using various values of p, q and L. The CMR value varies from 0.0 to 2. In Fig. 8a, when p = 0.85 (i.e., MU moves are often local) and q = 0.04 (i.e., incoming calls are most probably not local), the proposed scheme yields a remarkable reduction compared to other schemes. In Fig. 8b, when q increases (q = 0.45 i.e., incoming calls are mixture of local and non-local), the proposed scheme continues to outperform the HLR/VLRs scheme in all the cases and the database driven scheme in most of the cases. The database driven scheme outperforms the proposed scheme only when L = 4 (i.e., new HLRs become closer to the root) and CMR is very low (i.e., mobility rate is much higher than the call arrival rate and MU's are often local since p = 0.85). Figure 8e shows that when p = 0.04 and q = 0.85 (i.e., MU moves are often not local and incoming calls are often local), the proposed scheme outperforms other schemes when L = 2 and L = 3. However, when L = 4, the performance of the proposed scheme approaches that of the HLR/VLRs scheme and does better than that of the database driven scheme when the CMR <1 (i.e., call arrival rate is lower than mobility rate). When p increases to 0.45 (Fig. 8d), the proposed model results in a significant cost reduction compared to other schemes. Figure 8c shows that when p = 0.5 and q = 0.5 (MU's moves and incoming calls are mix of local and non-local), the proposed scheme outperforms the HLR/VLRs scheme. It also outperforms the database driven scheme when L = 2 and L = 3. However, when L = 4, both schemes' performance is equal.

CONCLUSIONS

In this study, we have proposed a new architecture for improving the location management in PCS networks taking into consideration the specific features of the mobile networks. The proposed architecture eliminates most of the drawbacks of the HLR/VLRs and database driven architectures. We have elaborated all the possible scenarios of the location update and the location search procedures and introduced an analytical model to study the performance of the new architecture in comparison to the HLR/VLRs and database driven architectures. Performance analysis shows that the proposed architecture is potentially beneficial for large classes of users and can result in substantial reductions in total user location management cost.

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